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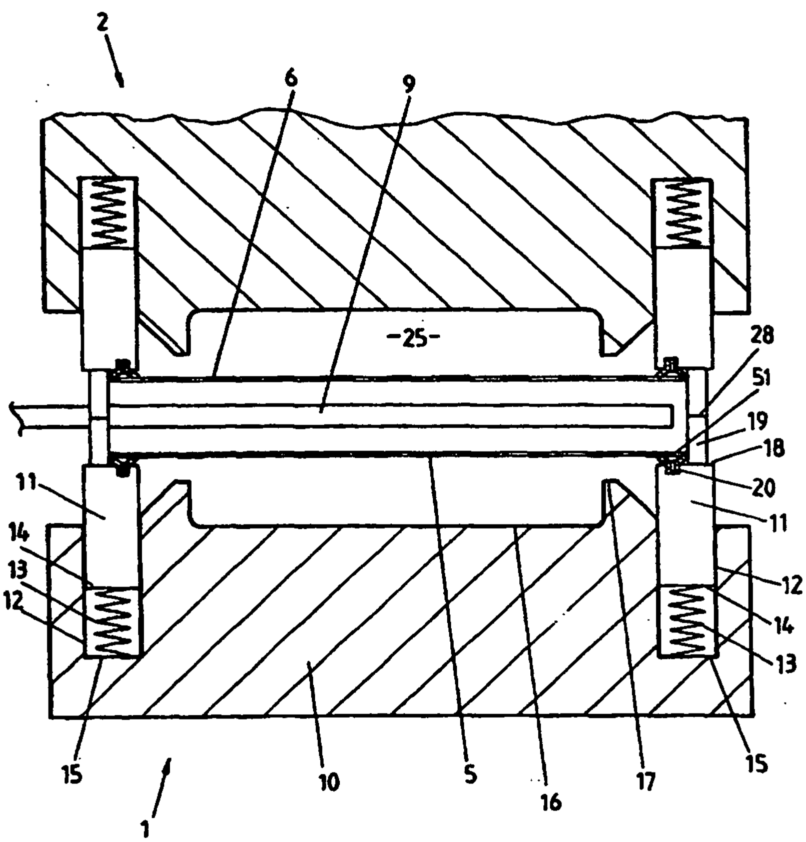
(54) Title: APPARATUS AND METHODS FOR TWIN SHEET THERMOFORMING

(57) Abstract

Apparatus for twin sheet thermoforming has each mould half incorporating a sheet support means which can hold a sheet by its edge and support the sheet during heating and wherein at least one of the sheet support means can retract during thermoforming. The sheets are supported clear of each mould half by the supports but are heated from between. A movable heater may carry sheets while simultaneously heating and transfer heated sheets to the mould halves of the thermoforming apparatus.



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APPARATUS AND METHODS FOR TWIN SHEET THERMOFORMING

BACKGROUND TO THE INVENTION

Field on the Invention

This invention relates to apparatus and methods for twin sheet thermoforming and in particular to improve methods and apparatus which do not require a sheet supporting framework.

Summary of the Prior Art

Twin sheet thermoforming is becoming increasingly popular in formation of large articles. Applications such as refrigerator cabinets and other large appliance cabinets have been envisaged, see for example US patent 5374118. That specification describes a process wherein twin extruded sheets are fed directly between opposed mould halves which are then brought together to form the panels of a cabinet. Such a method creates significant material handling problems and material wastage problems with the material being continuously extruded while the moulding process is a non continuous process. Consequently it is considered more appropriate in this area to cool thermoplastic sheets which can be heated immediately before moulding.

An example of such a method is depicted in PCT publication WO 96/25287 which shows a typical thermoforming process with the pair of sheets held and separated by a framework. The sheets are heated external of the mould, the framework carrying the sheets is interposed between the two mould halves and the mould halves are brought together with the framework supporting the sheets therebetween. This process contains many time consuming steps within the one product cycle which in turn adds additional complexity to the machine, require additional factory space and involve significant additional equipment if the process is to be operated in automatic fashion.

It is therefore an object of the present invention to provide apparatus and/or methods for twin sheet thermoforming which goes some way towards overcoming the above disadvantages or which will at least provide the public with a useful choice.

SUMMARY OF THE INVENTION

In a first aspect the invention consists in apparatus for twin sheet thermoforming comprising:

a pair of opposed mould halves relatively movable between an open position and

a closed position during the thermoforming process,

sheet support means associated with each said mould half, each mould sheet support means connected to its respective mould half and configured to hold a thermoplastic sheet around its edge, the sheet support means configured to hold the respective sheet apart from one another with said mould halves in their open position, each said mould half, its respective support means, and a sheet held in place by said support means together defining a pressurised volume, and

means associated with each said mould half which can create a controlled pressure differential between its respective defined volume and the outside thereof.

In a further aspect the invention consists in a method of twin sheet thermoforming comprising:

holding a heated thermoplastic sheet on each of a pair of mould halves, in a manner to provide a sealed volume between said sheet and said mould half, while controlling the air pressure differential between each space enclosed between a respective sheet and its respective mould half to guard against sagging of either said sheet,

altering said pressure differentials to ensure that the narrowest space between the sheets occurs at, and only at, portions thereof intended to become in contact and form seams therebetween,

moving said mould halves toward one another while increasing the effect of the pressure differentials, and causing each said sheet to seat itself against an annular weld region, and

continuing to bring said mould halves together to bring together said weld regions and cause a seam to be created between said weld regions.

In a still further aspect the invention consists in apparatus for twin sheet thermoforming wherein each mould half incorporates a sheet support means which can hold a sheet by its edge and support the sheet during heating and wherein at least one said sheet support means can retract during thermoforming.

To those skilled in the art to which the invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the scope of the invention as defined in the appended claims. The disclosures and the descriptions herein are purely illustrative and are not intended to be in any sense limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross sectional elevation of a twin sheet thermoformer with sheets and heater in place according to the embodiment of the present invention wherein the secured sheet edges remain separated,

Figure 2 is a perspective view of a part of the thermoformer of Figure 1 showing the sheet support means, an abutment member and a section of the mould cavity,

Figure 3 is a cross sectional elevation of a part of the thermoformer of Figure 1 with the heater now removed and the thermoforming process partly progressed,

Figure 4 is a cross sectional elevation as in Figure 3 with the thermoforming process further progressed,

Figure 5 is a cross sectional elevation as in Figure 4 with the thermoforming operation substantially completed and the twin sheets seamed together,

Figure 6 is a cross sectional elevation of twin sheet thermoforming apparatus according to an alternative embodiment of the present invention wherein the seam forming mould edges are incorporated in the sheet support means and in-mould trimming of the finished product can be achieved,

Figure 7 is a cross sectional elevation of part of the apparatus of Figure 6 with the thermoforming operation partly progressed,

Figure 8 is a cross sectional elevation as in Figure 7 with the thermoforming operation further progressed with the sheets just joined,

Figure 9 is a cross sectional elevation as in Figure 8 with the thermoforming operation almost complete, and

Figure 10 is a cross sectional elevation as in Figure 9 wherein the thermoforming operation has been completed and in-mould trimming has been accomplished by the guillotining effect between the upper sheet support means and the lower mould half,

Figure 11 is a cross sectional elevation through a sheet support member accoding to one embodiment of the present invention,

Figure 12 is a cross sectional elevation through twin sheet forming apparatus according to a further alternative embodiment of the present invention,

Figure 13 is a cross sectional view through twin sheet forming apparatus according to Figure 1 and a sheet carrying heater assembly according to a further aspect of the present invention,

Figure 14 is a cross sectional elevation through a region of twin sheet forming apparatus and associated sheet carrying heater assembly depicting clamps used in sheet transfer and including some hidden detail in shown in broken line,

Figure 15 is a perspective view of one embodiment of heater apparatus adapted to accommodate sheets of differing sizes, and

Figure 16 is a perspective view of an alternative embodiment of heater apparatus

adapted to accommodate sheets of differing sizes.

DETAILED DESCRIPTION

With reference to Figure 1 apparatus for twin sheet thermoforming is shown in cross section having a lower mould half 1 and an upper mould half 2. The thermoformer is shown with a pair of thermoplastic sheets 5,6 in place. Each sheet 5 or 6 is supported on its respective mould half 1 or 2 by a sheet support means 11 movably connected to a general body 10 of the mould half. The sheet support means in the preferred form is configured as an annular support member 11 fitted within an annular groove 12 which surrounds the mould cavity 16 of the mould half.

The sheet support member 11 holds the sheet along its edge 51, for example by use of an annular vacuum seal 20. Other means of securing the sheet around its edge may be used instead. For example a series of hinged and locked down clamps which could be manually or automatically operated, for example by solenoid or pneumatic means, could be used. Figures 11, 12 and 14 illustrate means for securing the sheet of this type and will be described in detail further on.

The support member 11 is shown in what is preferably a substantially fully extended position, which for example may be limited by a series of dowels and slotted holes or any other suitable means, and is able to be depressed into the channel 12 so that the mould half bodies 10 may be brought together until opposed seam regions 17 of the mould halves are substantially abutting. A series of springs 13 are disposed within the channel 12, between the bottom face 13 of the support member 11 and the base 15 of the channel 12 to provide graduating and increasing resistance to the depression of the support member 11. Clearly means other than springs may be provided such as carefully controlled mechanical actuators, hydraulic or pneumatic actuators or any other suitable devices, springs merely being among the least complex options.

Depression of the sheet support 11 into the channel 12 occurs automatically when the mould half bodies 10 are brought together in their thermoforming process, for example by the abutment of the support members 11. To create sheet separation similar to existing clamp frame assemblies abutting members 19 may be provided extending from the opposed surfaces 18 of the support members 11 to provide an abutment 28 therebetween. The abutting members 19 also allow reasonable access between the sheets, for example, for insertion of radiant heaters 9 to heat the thermoplastic sheets 5, 6. Where insertion of the heater, for example, may require additional separation this may be achieved by

controlling the platen separation or by having one or more of the abutting members 19 proportionally longer and being resiliently depressible into a cavity by that amount of its length. As can be seen in Figure 2 this abutment, while being completely rigid given the accurate location of the mould halves in a general thermoforming operation will still allow substantial free space for accessing the mould interior. In addition it is expected that such abutment means will be provided only down the sides of the mould halves so that the ends may remain completely open and sheets 5,6 may be easily inserted between the mould halves to be picked up and retained by the securing means 20.

Preferred methods of sheet loading and heating will be described later with reference to Figures 13 to 16.

Referring now to Figures 1 to 5 a thermoforming method accomplished by the apparatus of Figure 1 is demonstrated. In Figure 1 the sheets are shown with the heater 9 disposed therebetween. The heater 9 may for example comprise a simple electric radiant heater, and is used to raise the thermoplastic sheets 5, 6 to an appropriate thermoforming temperature before proceeding. The heater 9 is subsequently withdrawn.

During the heating process the sheets 5, 6 will become softened to the point where they can no longer support their own weight. This will typically become particularly important once the sheets reach their glass transition temperature. For ABS plastic sheet this will occur at around 90C. To alleviate any effect of droop the pressure in each of cavities 24 and 25, defined by each sheet 5, 6 and its respective mould half 1, 2 can be controlled as appropriate to support the sheets.

Details of each mould half for thermoforming and the mould cavities themselves are not shown, including the small access channels and air holes provided into the mould cavity 16 which are used in the thermoforming process to control the pressure in the mould cavity. These same holes may be used in supporting each of the sheets against sagging. Clearly to prevent sagging during heating, the pressure in cavity 25 will be kept below the ambient pressure and the pressure in cavity 24 should be kept above the ambient pressure.

Pressure based sheet support systems of various types are known in the thermoforming art. An example practical in the present application uses a light beam level sensor on one side of the sheet to detect whether the "bubble" of the sheet is presently interrupting the beam. Depending on whether the sheet is suported from above or below

and which side of the sheet the sensor is on, the controller controls the pressure in the support cavity to bring the sheet into a favorable condition. An improved version of this incorporates a controlled leak between the support cavity and the ambient room and a minimum pressure (positive or negative) application time, so that the "bubble" is caused to continually oscillate across the boundary of the light beam in accordance with the hysterisis of the system.

This control of sheet sagging is maintained until the sheet reaches the thermoforming temperature. For ABS plastics typically this will be above 140C. Other considerations such as the complexity of the shape to be formed may dictate a higher forming temperature.

The total heating time for a sheet will depend on the material, thickness and heater power. Typical total times for the heating process when using ABS sheet from 2-3mm thick, and heating at a rate giving efficient production without sacrificing sheet quality, would be 120 seconds, with the sheet benefiting from active support for at least the last half of the total time.

Referring now to Figure 3, the heater 9 has been withdrawn and the mould halves have been brought together to a small extent. The abutment 28 between abutment members 19 of the support members 11 has caused a compression in the spring 13 between the faces 14 and 15 of the support member 11 and the mould channel 12 of the mould body 10, so that each of the support members 11 have been depressed slightly. Furthermore the pressures in cavities 24 and 25 have now been adjusted, so that the positive pressure in cavity 24 has been eased off and perhaps even a vacuum is now being applied, and the vacuum and cavity 25 have been increased. The effect is to draw the softened thermoplastic sheets 5, 6 apart, which together with the closure of the mould has caused a portion 52 of each thermoplastic sheet to contact a seam region 17 of its respective mould half.

Looking now at Figure 4 the mould halves continue to be brought together, with the abutment 28 causing further compression in the spring 13 and further depression of the support members 11. At the same time the vacuum in cavity 25 and 24 is being increased to continue to draw the thermoplastic sheets into place in the mould cavities 16 and thereby begin to form the finished shape, for example portions 53 of the sheet now contacting the internal surface of the mould cavity. The securement of edge 51 now becomes less critical, however it is still considered advisable that the edge be securely

fastened.

Referring now to Figure 5, the mould halves 1 and 2 have now been completely brought together, fully compressing the springs 13 such that the support members 11 are now fully depressed into their respective cavities 12. The continued application of vacuum in the mould cavities 16 causes the respective sheets 5, 6 to be drawn fully into the cavities to thereby conform to the cavity shape. The seam regions 17 of the mould halves 1 and 2 have come substantially into abutment forming a seam 55 between the two sheets 5, 6 of thermoplastic material. Preferably the mould halves 1 and 2 have been brought together closer than the combined thickness of the two sheets in the region of seam forming regions 17, so that material has been forced away from the seam 55, so as to form for example a reinforcing bead 56 on the inside of the thermoformed part.

The thermoforming process is thus basically complete. Now the part may be allowed to cool, foam may be injected, the part may be removed and trimming may take place as appropriate. As an alternative to extracting the part from the mould prior to trimming, an in-mould trimming type device may be provided, for example, a knife or cutting blade, or a guillotine adaptation such as will be described with reference to Figures 6 to 10 may be incorporated into the mould design, at the seam region 17, for example as depicted in Figure 12.

In Figure 12 the seam region of the lower mould half is provided with a breakaway member 109 which can recede into channel 110 upon application of sufficient pressure against the pre-compressed spring 111. Upon continued closure of the mould halves the edges 112 and 113 of the upper and lower mould halves respectively cooperate to shear off the forming flange from the part. This action will be described further below with reference to Figures 6 to 10.

Referring now to Figure 6 an alternative embodiment is depicted which achieves the same goal of eliminating the support frame and allowing heating of the thermoplastic sheets from a single heater disposed therebetween, but which also achieves the objective of in-mould trimming by a guillotining type approach using the depressible support members in the guillotining process. It should be noted that in this embodiment, and in the embodiment of Figures 1 to 5 it would be equally possible to provide only a single depressible support member and achieve the same overall effect. For example, in Figures 6 to 10 the upper sheet support member 41 may be fixed without substantially altering the operation of the machine.

Looking now at Figure 6 the two mould halves are no longer substantially the same. The upper mould half 4 has an annular sheet support member 41 depressible into a channel 42, with springs 45 disposed between the opposed faces 44 and 43 to provide a resilience and opposition to such depression. A sheet 8 is retained by the vacuum channel seal 48, which is evacuated through tubes 47, much as in the embodiments of Figures 1 to 5. In the embodiment shown in Figure 6, the internal face of the depressible member 41 itself forms a part of the mould cavity. As discussed briefly above, the member 41 in Figure 6 could equally be formed integral and as a complete part of the non movable part of the mould body 40 without significantly affecting the performance of the thermoformer. The sheet support member 41 has a small seam forming region 49 protruding at the lower face thereof, adjacent the vacuum seal 48 which retains the edge 80 of the sheet 8. The effect of this protruding edge is demonstrated in the later figures.

The lower mould half 3 has mould half body 30, with the sheet support member 31 retained within a channel 32. First springs 35 are provided in the cavity 32 to act between the opposed faces 34 and 33 of the support member 31 and the main body 30 respectively. Further springs 36 are provided in the base of the channel 32, which will act between the faces 34 and 33 only once the support member 31 is sufficiently depressed within the channel. The depth of channel and height of support member 31 are such that the further springs 36 will be encountered once the support member 31 has been sufficiently depressed that the seam forming region on the upper face thereof is at the level of the mould surface 26. The reasons for this will be shown with respect to Figures 7 - 10. The edge 70 of the sheet 7 is secured by vacuum seal 38, evacuated through tubes 37. For reasons which will be apparent, with the tubes 37 extending out the side of the support member 31 a rebate is provided in the mould body 30 to allow for the depression of the support member 31.

As in the earlier embodiment the use of springs is a matter of choice based on their simplicity. Many other methods of allowing the depression of the sheet support members can be envisaged, such as precise mechanical actuation, pneumatic support or hydraulic support. These various possibilities do not depart from the invention at hand.

In use a heater may be inserted between the thermoplastic sheets and used to heat the thermoplastic sheets to a thermoforming temperature in substantially the same manner as in Figure 1. Further preferred methods of loading and heating the sheets will be described below with reference to Figures 13 to 16. Once the heater is removed the mould halves 3, 4 are slowly brought towards one another, while the cavities 22, 23 previously

used to support the sheets 7, 8 against sagging, are evacuated to separate the sheets as depicted by the region 71 and 81 of the sheets in Figure 7. At this stage neither member 31 or 41 has begun to be depressed into its respective cavity as the support members are not yet abutting to cause compression in the respective springs 35, 45.

Referring now to Figure 8 the thermoforming process is shown advanced still further, with the mould halves 3, 4 brought together to such an extent that the sheet support members 31 and 41 are now in abutment with the edges 70, 80 of the respective sheets 7, 8 contacted therebetween, and now in contact with the seam regions 39, 49 of the support members 31, 41. Continued evacuation of the cavities 22, 23 has led to the more advanced formation of the respective sheets, with for example portion 72 of the lower thermoplastic sheet now contacting the mould surface 26.

Referring now to Figure 9 the process is shown still further advanced by continued movement of the mould halves. The springs 45 between the face 44 of the upper sheet supporting member 41 and the face 43 of its respective channel 42 are now fully compressed. The springs 45 between the face 34 of the lower support member 31 and the face 33 of its respective channel 32 are now compressed to such an extent that the support member 31 has come into contact with the further springs 36 provided in the channel. However, unlike the upper support member 41, the lower support member 31 still has some available depressive freedom. The thermoformed part is now more fully formed with the lower sheet 72 now completely formed against the mould surface 26 and the upper sheet 82 almost fully formed, with continued vacuum in the small remaining part of the cavity 23 set to accomplish that task. A weld 74 is beginning to form in a region between the abutment of the support members 31 and 41.

The final stage of the process is depicted in Figure 10. The mould halves have been further brought together. The upper support member 41 was already fully depressed into its respective channel. The lower support member 31 has been subject to further depression into its channel by further compression of the springs 35 and by compression of the springs 36 between the face 34 of the support member 31 and the face 33 of its respective channel 32. The resistance of the springs 35 and 36 has meant that significant pressure has been placed in the abutment between seam regions 39 and 49, to displace plastic material from the weld region 76, and form a bead 75 on the inside cavity of the formed component in the weld region, this bead will provide substantial reinforcement to the weld. The continued movement has depressed the weld region 39 of the support member 31 below the edge 27 of the mould body 30, such that the weld region 49 of the

support member 41 overlaps the edge 27 of the mould body 30, and with sufficiently close tolerance between the two, a guillotining action has sheared off the seam and support region 77.

Looking at the apparatus and processes depicted and described it is clear that the present invention provides a method whereby the sheets may be supported in association with each of the mould halves without the use of a separate supporting frame, and that the thermoforming process may be conducted in a simple operation by bringing the mould halves together. In addition in the system as outlined with respect to Figures 6 to 10 an in-mould trimming operation without the need for additional knives and parts, and which accomplishes a reinforcing bead in the finished component is also achieved.

Figure 11 depicts an alternative arrangement for securing a thermoplastic sheet 90 to a support member 91. In this arrangement a clamping toggle 92 is mounted for pivotal movement about a pivot axis 93. This may involve supporting the toggle 92 off a lug 94 extending from the support member. The toggle 92 includes a clamping arm 95 which has a clamping surface 96 adapted to bear against the surface of the sheet 90. An actuator 98 is connected to the clamping toggle 92 to operate it through a pivotal movement typically of at least 90 degrees. The actuator 98 may comprise a solenoid which has the advantage of controllable bearing pressure. A resilient strip seal 99 is provided in a channel 100 in the surface of the support member 91. The resilient strip may be formed for example from silicone rubber, and has a sealing edge 101 raised substantially from the surface 102 of the support member. In use the clamping surface 96 presses the sheet against the resilient strip seal 99. It is preferred that a number of these clamps are provided, and that they are at sufficient spacing to ensure an adequate seal of the sheet 90 against the seal 99 around the entire periphery of the sheet. For a 3mm ABS sheet a typical arrangement would have 45mm width toggles separated by 50mm spaces.

With reference to Figure 12 the spaced apart clamps may at some points be interspersed with abutments 103, and the toggles 107,108 may be provided at alternate positions on the upper (105) and lower (106) mould halves respectively so that the movement envelope of the toggles of each mould half is not impeded by the toggles of the other mould half.

Referring now to Figures 13 to 16 preferred methods and apparatus for loading and heating sheets are shown. Figure 13 depicts the general method as applied to forming apparatus such as that of Figure 1. A moveable heater box 115 is provided which can

move into a position between the upper and lower mould halves. The heater box includes upper and lower heater supports 117, 118 which support each of the upper and lower sheets for loading onto the mould halves 119,120 respectively. A heater 121 is provided between the sheets 122,123. Preferably both upper and lower heaters are provided so that heating of the upper and lower sheets can be independently controlled in accordance with the influence of sheet thickness. This arrangement allows preheating of the sheets on the heater box prior to introduction between the mould halves. The heater box acts as both the heater and the sheet carrier so the time required for heating the sheets is effectively overlapped with time that would otherwise be expended in sheet transport.

In one method the sheets are preheated on the heater box to a temperature which is ensured to be below the glass transition temperature (for example 70C). This preheating may be conducted more slowly than would be done if the sheets were already in place, which is preferable as it ensures an even heat distribution and penetration, facilitating later further heating. The heater box, carrying the sheets, is subsequently moved into position between the mould halves. Up until this time the mould halves may have been completing an earlier thermoforming sequence or cycle. The sheets are then transferred to the sheet support members of the respective mould halves. Once transferred to the respective mould halves, support of the sheets through the controlled pressure systems already described is initiated and maintained. The heater applies further heating to bring the sheets up to the thermoforming temperature before being removed from between the mould halves. In the typical example using 3mm thickness ABS sheet referred to earlier this further heating may take 60 seconds. The heater is then removed and thermoforming begins as already described.

Actual transfer of the sheets involves either bring the mould halves together to bring each mould half into proximity with its respective sheet or alternatively movement of the heater box (or an upper or lower half thereof) to meet the respective mould half.

In an alternative method, which has additional reductions in the time of utilisation of the mould halves in each cycle, but which is more complex to implement where handling of different sheets by the same heater box is required, the heater box itself incorporates an upper 124 and a lower 125 controlled pressure cavity, each incorporating a peripheral sheet seal 126, 127 and supporting means which are sufficient to hold the sheet in a sealed condition against the seal. The heater is thus enabled to provide support to both the upper and lower sheets prior to transfer and the sheet may be raised to the thermoforming temperature before the heater box is shuttled into position between the

moulds for transfer. This reduces the time that the set of mould halves are required in each cycle allowing an increased number of cycles in a given production time. During transfer there is a transition time as support of the sheet is transferred from the pressure cavity of the heater box to the pressure cavity of the mould half.

Where the sheet size is set there is no great difficulty with holding the sheet in a sealed condition, and the peripheral suction seal and support depicted in Figure 13 is readily suitable. However there is some indication that conducted heat may cause the edge of the sheet to soften more than is desirable then the seal may be lost due to deformation of the sheet at the edge.

A clamping toggle based support and transfer system is depicted in Figure 14 which is readily suited to either heating and transfer method described above. This arrangement uses actuator controlled toggles 130 largely as depicted in and described with reference to Figure 11. The toggles 130 preferably grasp the sheet not directly on the seal member 131 but slightly to the outer side thereof. This allows the toggles 130 to operate in cavities 132,133 formed in the support members of the mould half 134 and the heater box 135 respectively without interference with the sheet 136 or with the seals 131. Secondary clamps (not shown) may be provided which disengage prior to the transfer process for additional security if higher thermoforming temperatures are used which will reduce the integrity of the sheet in the peripheral area. A further cavity 137 may be provided for any abutment(s) of the respective mould half. It will also be appreciated that this clamping arrangement can be applied to the sheet support members of the mould halves in the thermoforming method of Figure 6, as it overcomes the interference difficulties that might otherwise be associated with use of a mechanical sheet clamping arrangement.

The heating of sheets prior to transfer presents considerable difficulty if a variety of sheet sizes is to be catered for and the sheets are to be raised to full thermoforming temperature, as adaptation of a peripheral sealing arrangement may be required. However if the method is restricted to heating prior to transfer only to below the glass transition temperature then it is possible to provide the heater box with supports adaptable to varying sheet sizes but which do not provide a peripheral seal. Examples of such arrangements are shown in Figures 15 and 16.

In Figure 15 the heater box 140 includes a plurality of suction support posts 141 spaced evenly throughout the heater box to support a sheet at a plurality of locations on

its undersurface irrespective of the sheet size or shape. The number and spacing of the support posts would need to be set in accordance with the strength characteristics of the sheet material at the intended transfer temperature.

In Figure 16 a heater box 145 includes a plurality of automatically moveable toggle clamps 142 which are adapted to automatically reposition along a series of tracks 143 on walls 144 reaching inwards across the heater box. Movement of the toggles may be effected by known means of linear actuation, and the toggles may be substantially in accordance with the arrangement shown in Figure 14.

In heater boxes adapted to take varying sheet sizes it is advantageous if the heater is controllable in sections so that only regions of the heater in direct juxtaposition with the sheet that is presently held above the heater are activated. This reduces wasted energy, and also ensures that free edges of held sheets are not subjected to additional radiant heating from heater elements not directly below the sheet. Where the heater is intended to be used with a wide variety of sheet shapes and sizes the heater may be formed from a large number of arbitrary zones, for example a grid of rectangular zones, which can be individually controlled, otherwise the shape and configuration of the zones may be specifically adapted to the range of sheets that will be used.

At an organisational level the present invention eliminates the need for adjustable or different fixed clamp assemblies which are required in conventional forming processes, and whose prescence is required during the entire forming process. It allows for moulds to be quickly changed and producing parts, introducing significant flexibility in the vacuum forming process over a large product range.

As the sheets are peripherally supported away from the mould surface the sheets remain sufficiently softened at the seam region to provide good fusion, as the seam region of the sheet contacts the seam region of the mould only immediately prior to fusing. This advantage is particularly apparent embodiments of the invention as disclosed where both sheet supports are able to retract.

Variations on the schemes depicted will be readily apparent and not all variations have been described or mentioned. Examples are the particular opportunities that exist in fixing one of the sheet support members in either forming method. Such modifications do not depart from the scope of the invention.

CLAIMS

1. Apparatus for twin sheet thermoforming comprising:

a pair of opposed mould halves relatively movable between an open position and a closed position during the thermoforming process,

sheet support means associated with each said mould half, each mould sheet support means connected to its respective mould half and configured to hold a thermoplastic sheet around its edge, the sheet support means configured to hold the respective sheet apart from one another with said mould halves in their open position, each said mould half, its respective support means, and a sheet held in place by said support means together defining a pressurised volume, and

means associated with each said mould half which can create a controlled pressure differential between its respective defined volume and the outside thereof.

2. Apparatus for twin sheet forming as claimed in claim 1 wherein one or more of said sheet support means is movable relative to its respective mould half, under pressure of an abutment between the said support means and the other said support means or mould half to thereby depress said support means relative to its respective said mould half.

3. Apparatus for twin sheet forming as claimed in claim 2 wherein both said support means are movable upon abutment with each other, there being abutment means which maintain a separation between said sheets with said sheet support means abutting, said sheet support means both becoming depressed relative to their respective mould halves upon movement of said mould halves to their said closed position, such that in use each sheet will come into contact with a seam forming region of its respective mould half, and with further movement of said mould halves towards said closed position said regions of said sheet which are contacting said weld forming portions of said mould halves come themselves into contact and are pressed together by the closure of said mould halves to form a seam.

4. Apparatus for twin sheet forming as claimed in claim 1 wherein said sheet support means includes a seamed weld region thereof with which, under sufficient vacuum in said enclosed volumes, said sheets come into contact, and which by closure of said mould halves toward said closed position are made substantially to abut and thereby bring the seam regions of said sheets together to form a seam.

5. Apparatus for twin sheet forming as claimed in any one of claims 1 to 4 including

means for automatically trimming the seam region from a formed part wherein one of said seamed regions may become depressed below the level of its mould half immediately adjacent said seam region such that the other said seam region and said mould half cooperate to remove said seam region in a guillotining action.

6. Apparatus for twin sheet forming as claimed in any one of claims 1 to 5 wherein said sheet support means include a resilient strip protruding from a face of said support means and a plurality of spaced apart clamping members, each said clamping member rotatable for a face of said clamping member to press the sheet against said resilient strip, the spacing of said clamping members being sufficiently close that a continuous peripheral seal is possible between the sheet and said resilient strip.

7. Apparatus as claimed in any one of claims 1 to 6 including a heater means and a heater moving means to move said heater means between said mould halves when apart, said heater means adapted to heat the pair of sheets from there between.

8. Apparatus as claimed in claim 7 wherein said heater means includes sheet support means on its upper and lower sides to hold a sheet on each of its upper and lower sides, such that when moved into position between the mould halves said sheets may be transferred to said sheet support means of said respective mould halves.

9. Apparatus as claimed in claim 8 wherein said heater means includes an upper and lower pressure cavity and a pressure supply path to allow the application of a separately controlled pressure to each of said upper and lower cavity, and said heater sheet support means of each of said upper and lower sides is adapted to peripherally seal with a said sheet such that in use each said sheet closes each said cavity.

10. Apparatus as claimed in either claim 8 or claim 9 wherein said sheet support means of said heater means includes a plurality of spaced apart clamping members and associated cooperating clamping surfaces, the clamping members of said heater means being positioned around the periphery of said sheet between the positions of the clamping members of said mould half sheet support means.

11. Apparatus as claimed in claim 10 wherein at least some of said clamping members of said heater means are each automatically movable to operate from a variety of positions, such that together with other of said clamping members they may adapt to hold sheets of differing sizes.

12. Apparatus as claimed in claim 8 wherein said sheet support means comprise suction support means which engage against, and hold said sheet on the non-mould face thereof and which are distributed across said heater means such that they can grip sheets of differing sizes.

13. Apparatus as claimed in claim 11 or claim 12 wherein said heater means includes a plurality of heater elements, said elements are arranged in regions, and regions of said elements are connected to control means for controlling which regions of said heater elements are activated in accordance with the size of sheet to be heated.

14. A method of twin sheet thermoforming comprising:

holding a heated thermoplastic sheet on each of a pair of mould halves, in a manner to provide a sealed volume between said sheet and said mould half, while controlling the air pressure differential between each space enclosed between a respective sheet and its respective mould half to guard against sagging of either said sheet,

altering said pressure differentials to ensure that the narrowest space between the sheets occurs at, and only at, portions thereof intended to become in contact and form seams therebetween,

moving said mould halves toward one another while increasing the effect of the pressure differentials, and causing each said sheet to seat itself against an annular weld region, and

continuing to bring said mould halves together to bring together said weld regions and cause a seam to be created between said weld regions.

15. A method as claimed in claim 14 including the steps of:

preheating said sheets on either side of a moveable heater box,

transferring said sheets to said mould halves, and

removing said heater box from between said mould halves.

16. A method as claimed in claim 15 wherein said preheating of said sheets is limited to heating not sufficient to bring the temperature of the said sheets up to their glass transition temperature, and said method includes the step of further heating said sheets to the forming temperature after transferring said sheets to said mould halves and prior to removing said heater box.

17 A method as claimed in claim 16 wherein said preheating of said sheets is sufficient to bring said sheets to their forming temperature, and said method includes the

steps of:

maintaining a positive pressure within a cavity enclosed by the upper sheet and the heater box and a negative pressure in a cavity between the lower sheet and the heater box

18. A method as claimed in any one of claims 14 to 17 wherein said step of transferring said sheets includes:

bringing said heater box between said mould halves,

bringing each said mould half and its respective half of said heater means together until a support means provided on each mould half contacts the respective sheet, and

taking hold of each said sheet with the respective said support means.

19. A method as claimed in claim 18 wherein said step of bringing each said mould half and its respective half of said heater means together includes bringing said mould halves toward one another.

20. A method as claimed in claim 18 wherein said step of bringing each said mould half and its respective half of said heater means together includes moving apart upper and lower sheet supports of said heater means.

21. A method as claimed in any one of claims 18 to 20 wherein said step of transferring said sheet includes the further steps of:

maintaining a controlled pressure in a space between each said sheet and the heater box sufficient to support each said sheet against sagging,

once said respective support means have taken hold of said sheet, gradually introducing a controlled pressure in a space between each said sheet and its respective said mould half, and compensating for said introduction in the pressures maintained in said spaces between each said sheet and the heater box, until each said sheet is fully supported against sagging by said pressures in said space between said sheet and its respective said mould half, and

releasing each said sheet from said heater box.

22. A method as claimed in any one of claims 14 to 19 including the further step of bringing said mould halves further together with one said seam region adapted to depress relative to its said respective mould half, its respective said mould half and the other said seam region cooperating to trim said seamed region from the formed part by a guillotining action.

23. Apparatus for twin sheet thermoforming wherein each mould half incorporates a sheet support means which can hold a sheet by its edge and support the sheet during heating and wherein at least one said sheet support means can retract during thermoforming.

24. Apparatus substantially as herein described with reference to and as illustrated by Figure 1 of the accompanying drawings.

25. A method for twin sheet thermoforming substantially as herein described with reference to and as illustrated by the accompanying drawings.

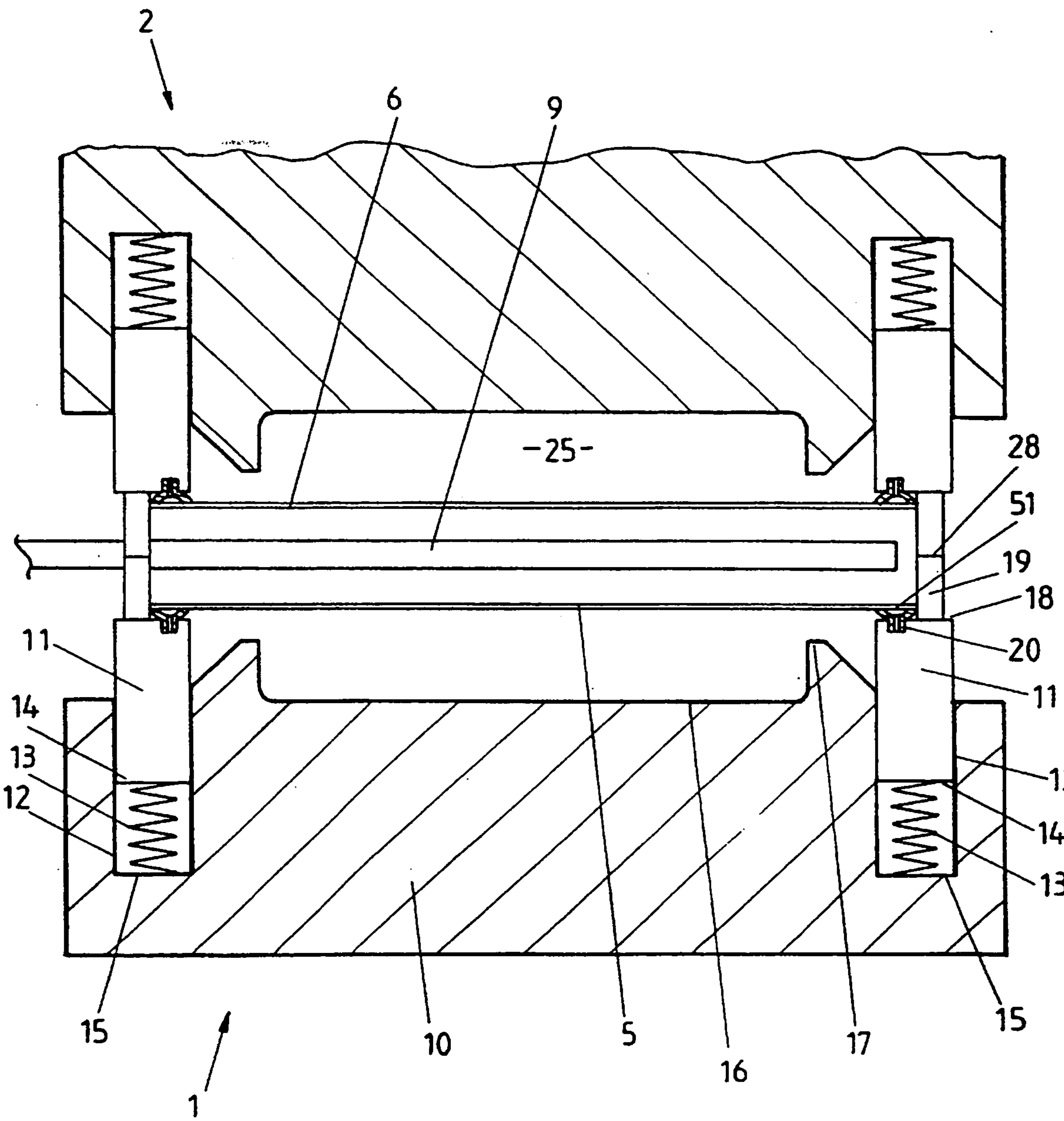


FIG. 1

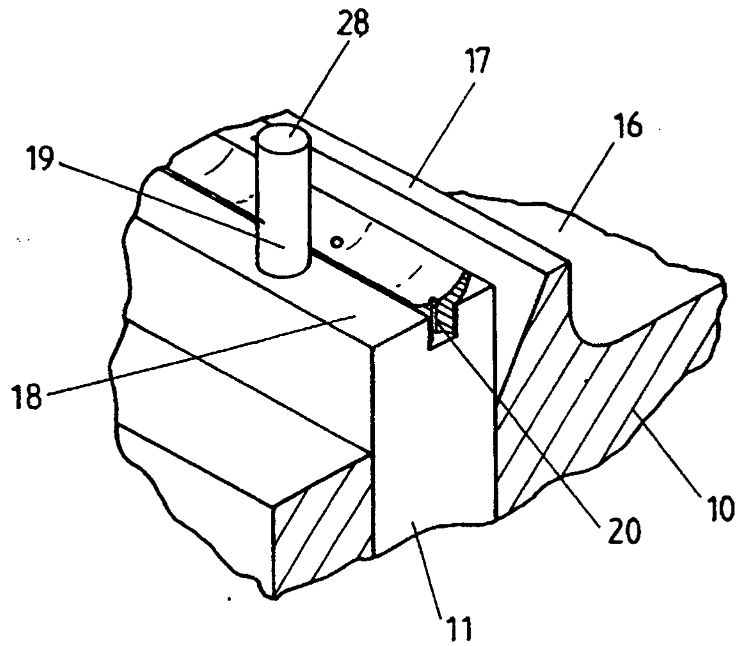


FIG. 2

FIG. 3

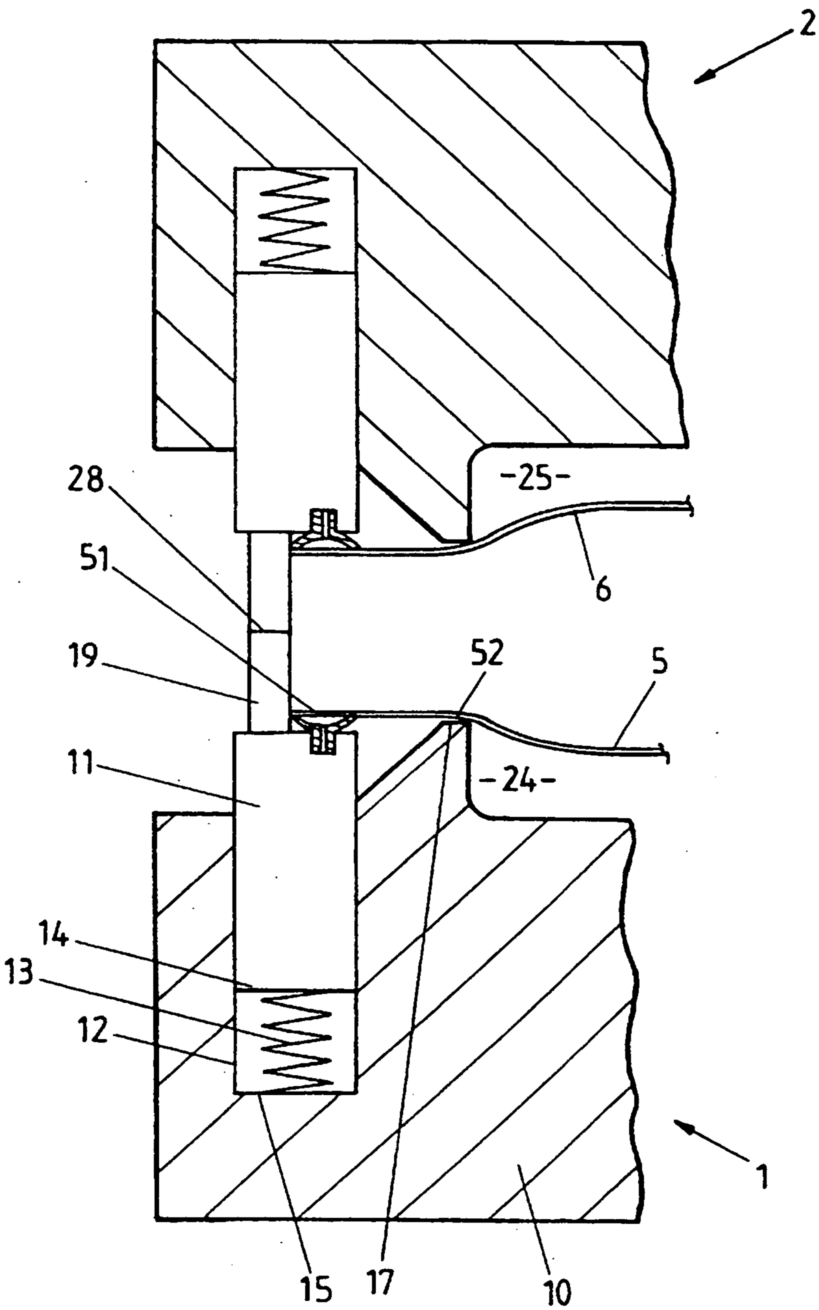


FIG. 4

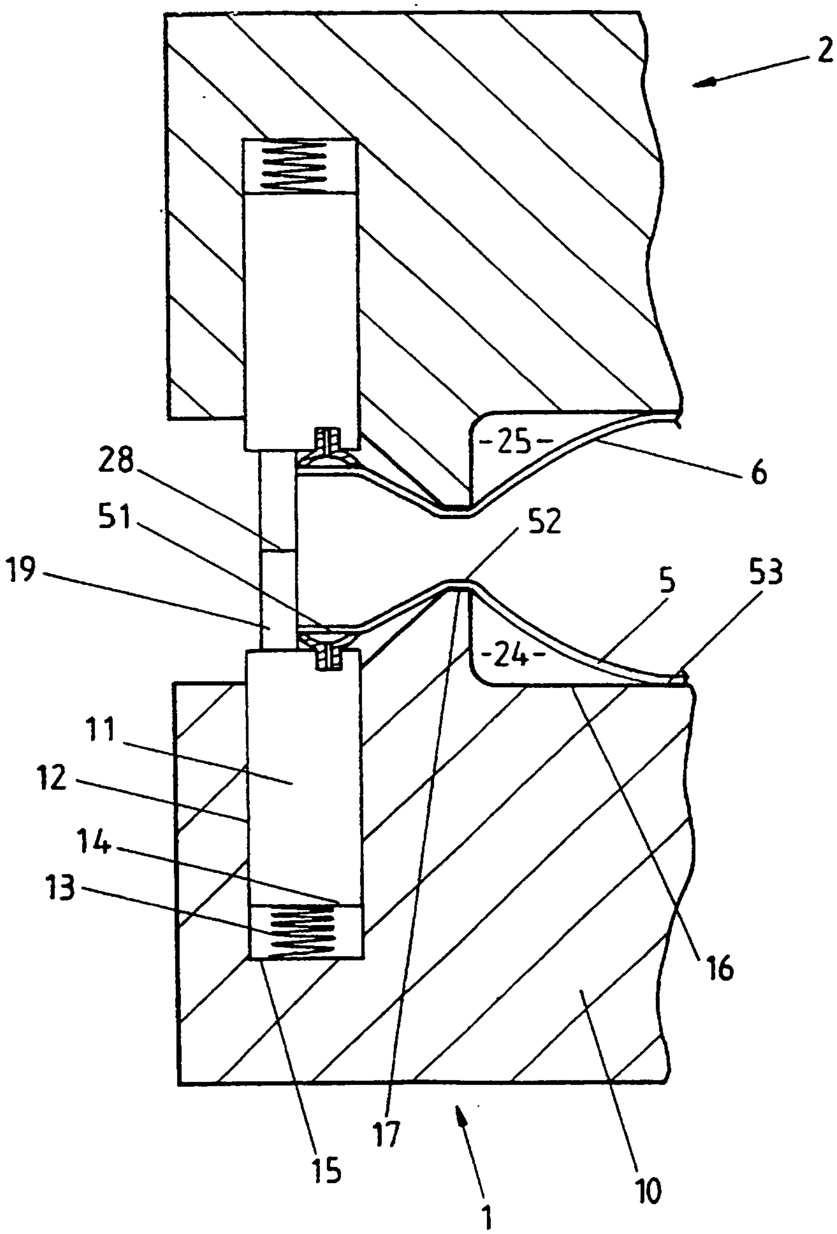
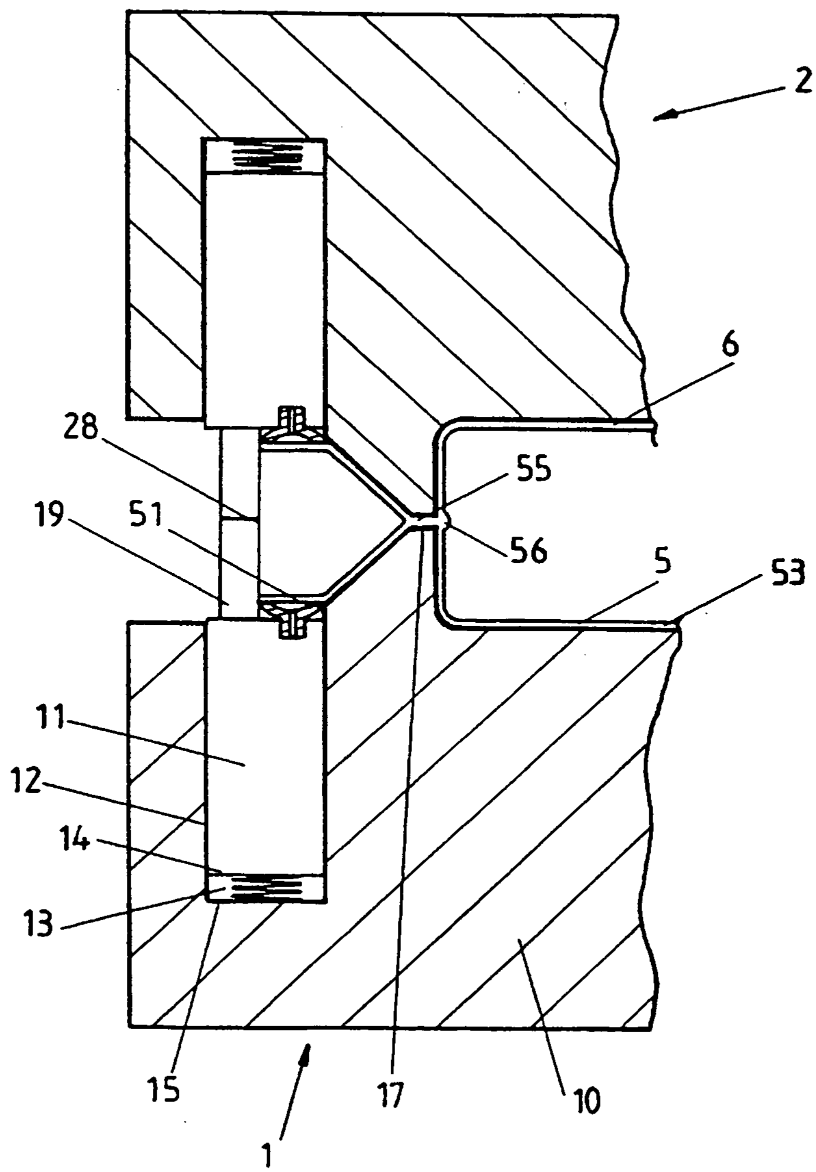


FIG. 5



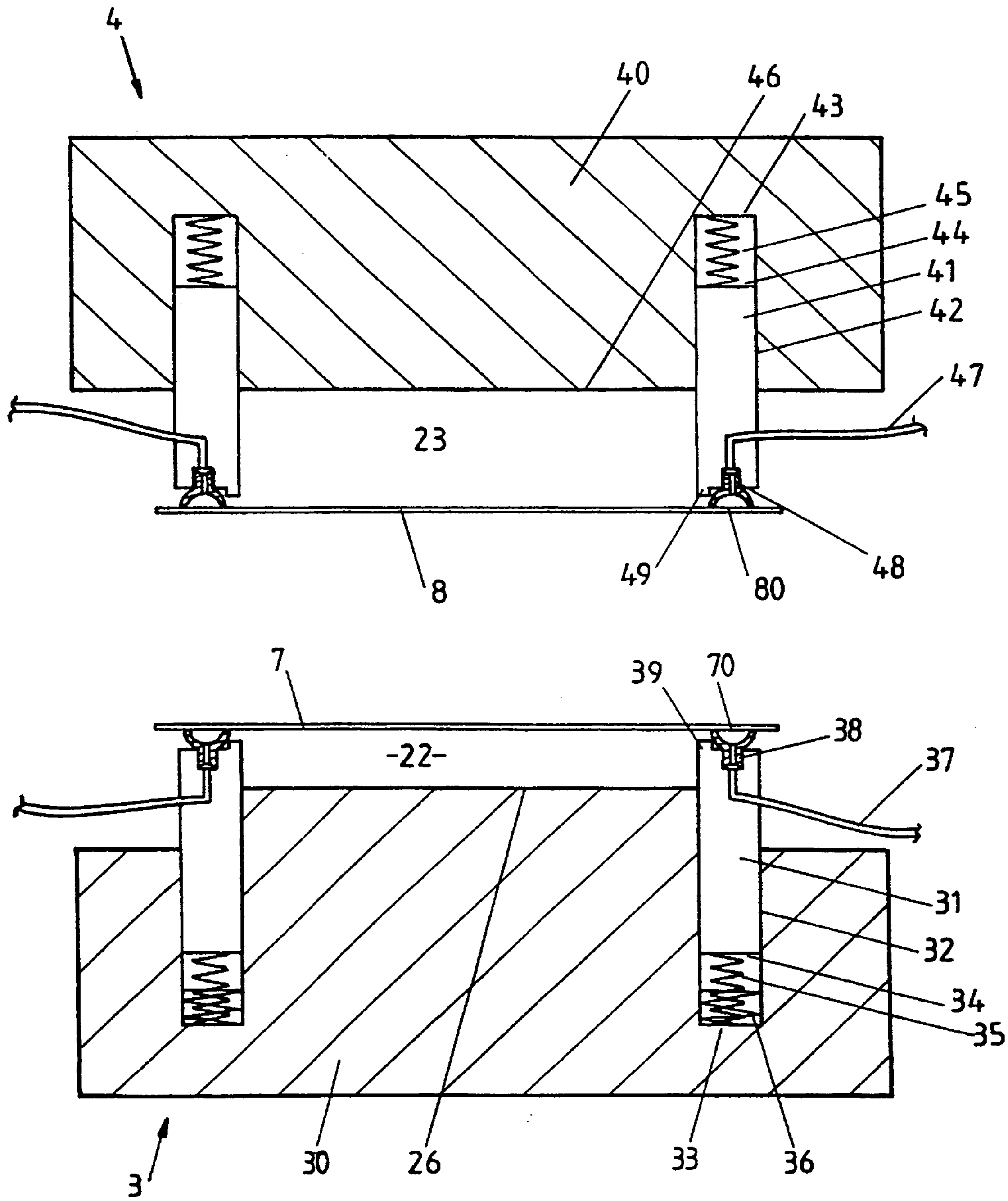

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FIG. 6

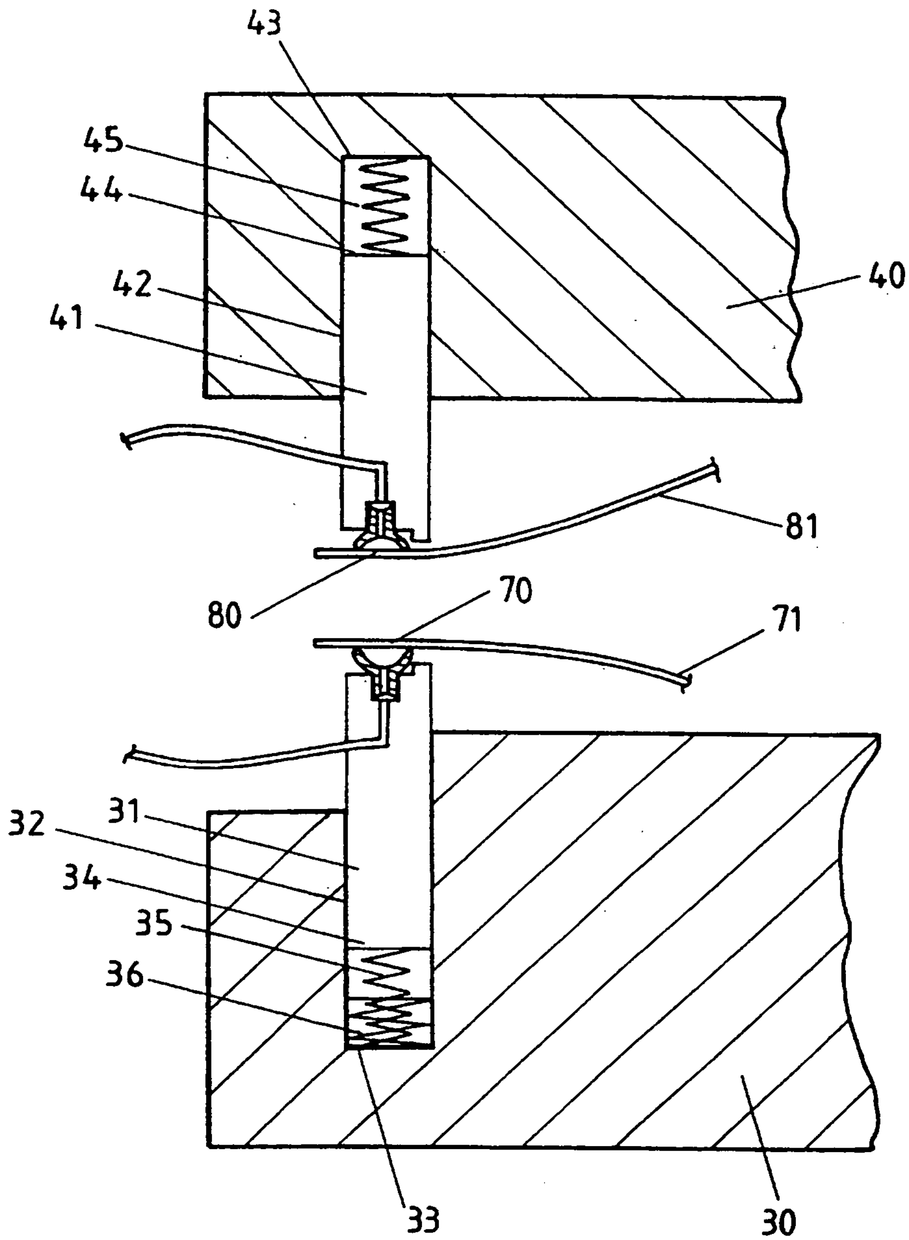

FIG.7

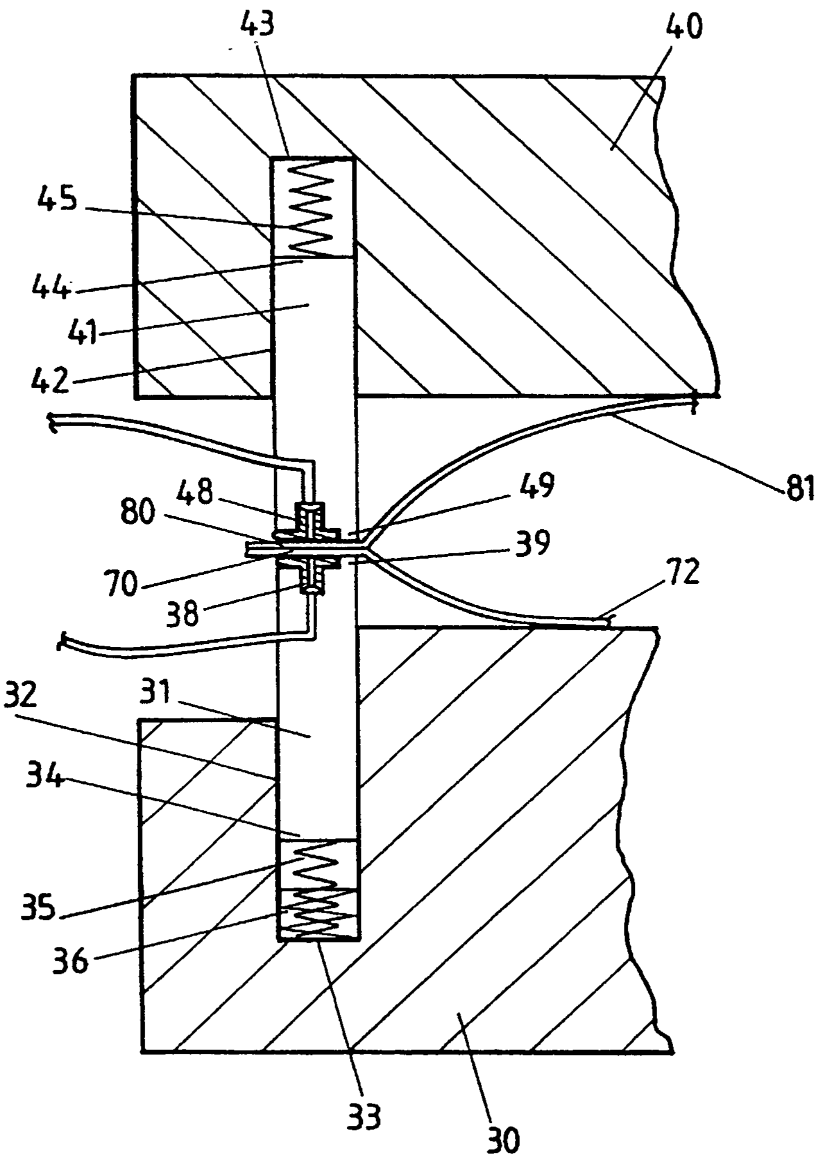

FIG.8

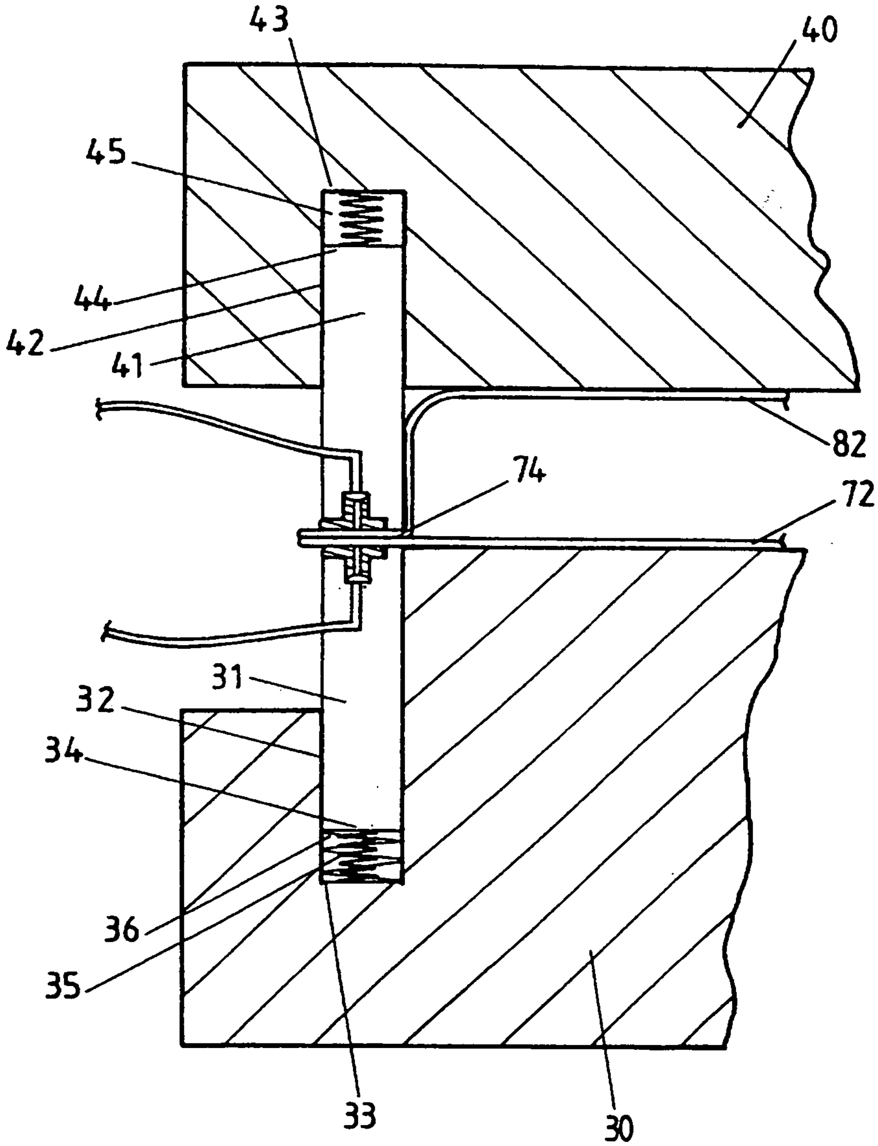

FIG. 9

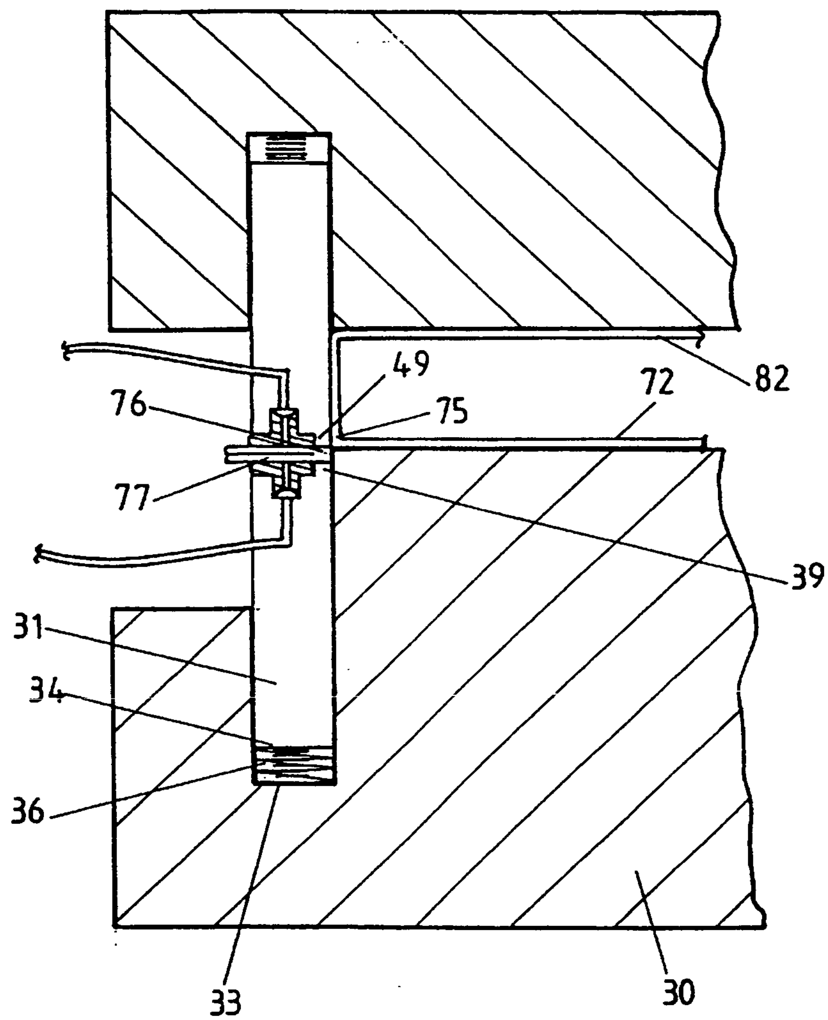

FIG. 10

FIG. 11

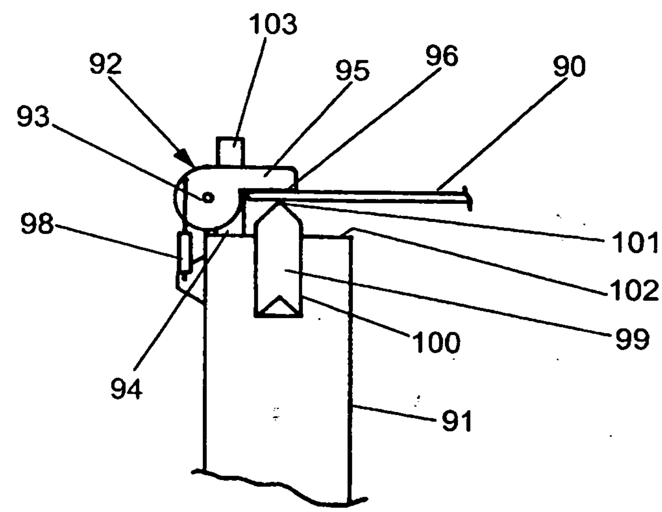
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FIG. 12

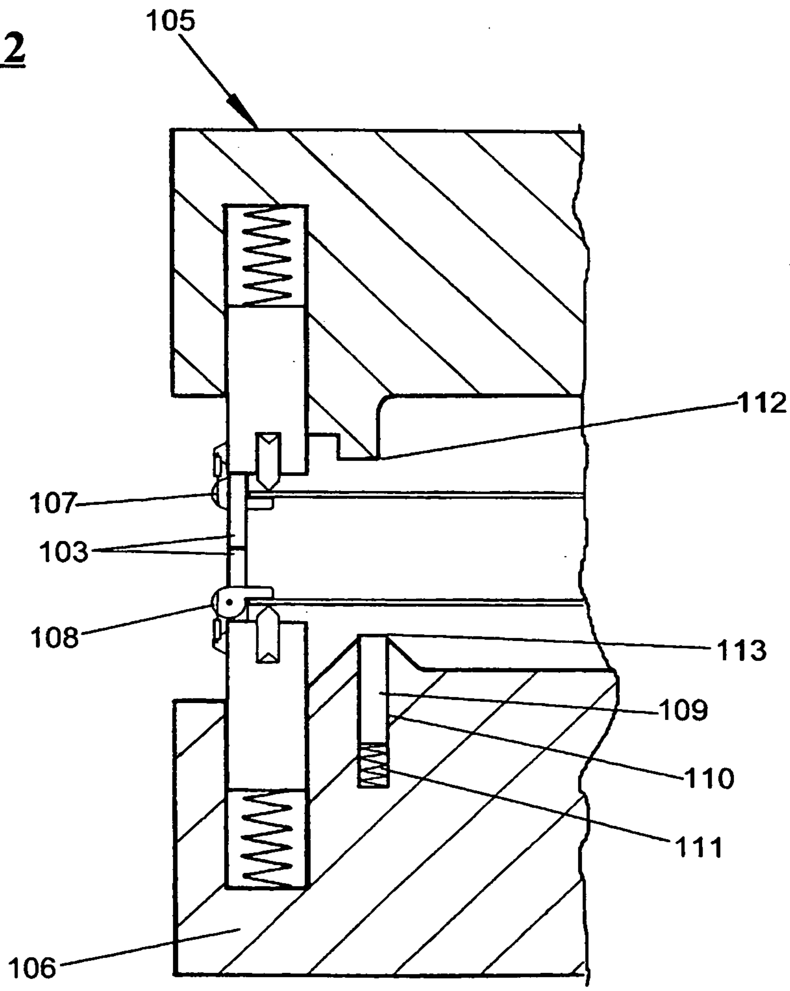
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FIG. 13

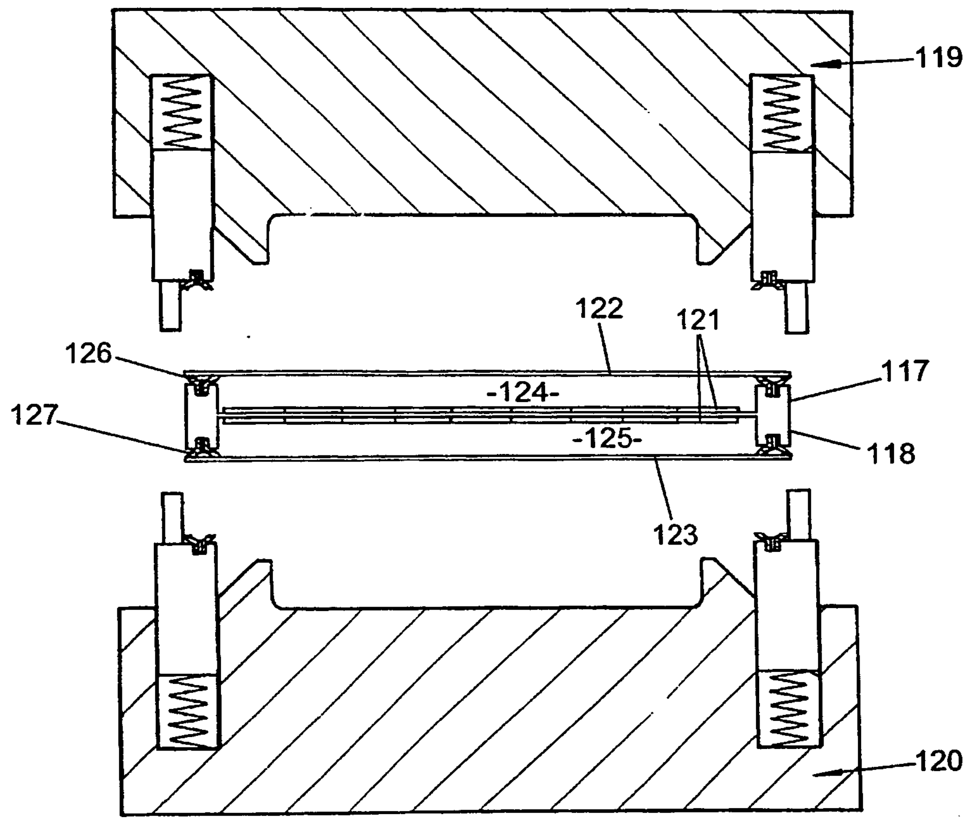
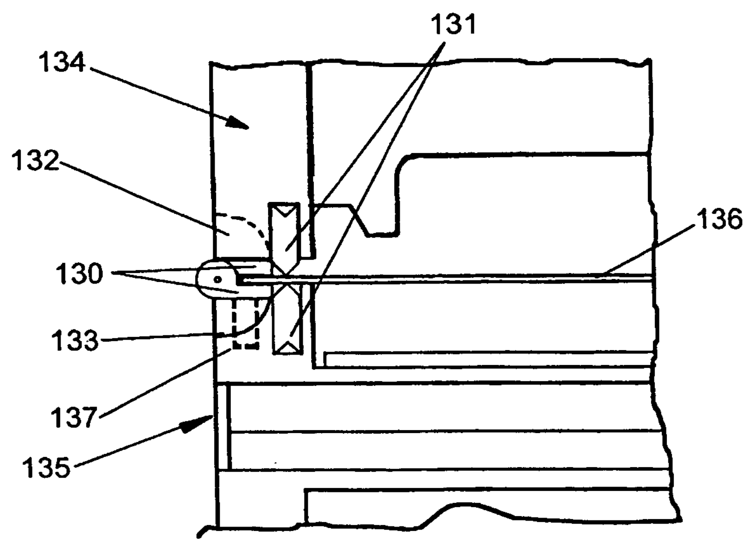


FIG. 14



SUBSTITUE SHEET (Rule 26)

FIG. 15

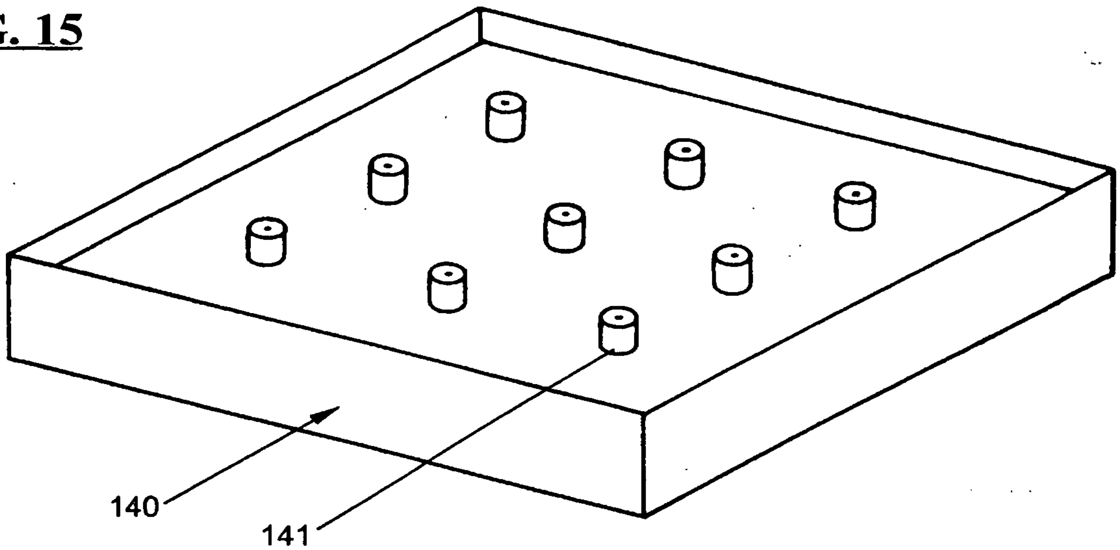
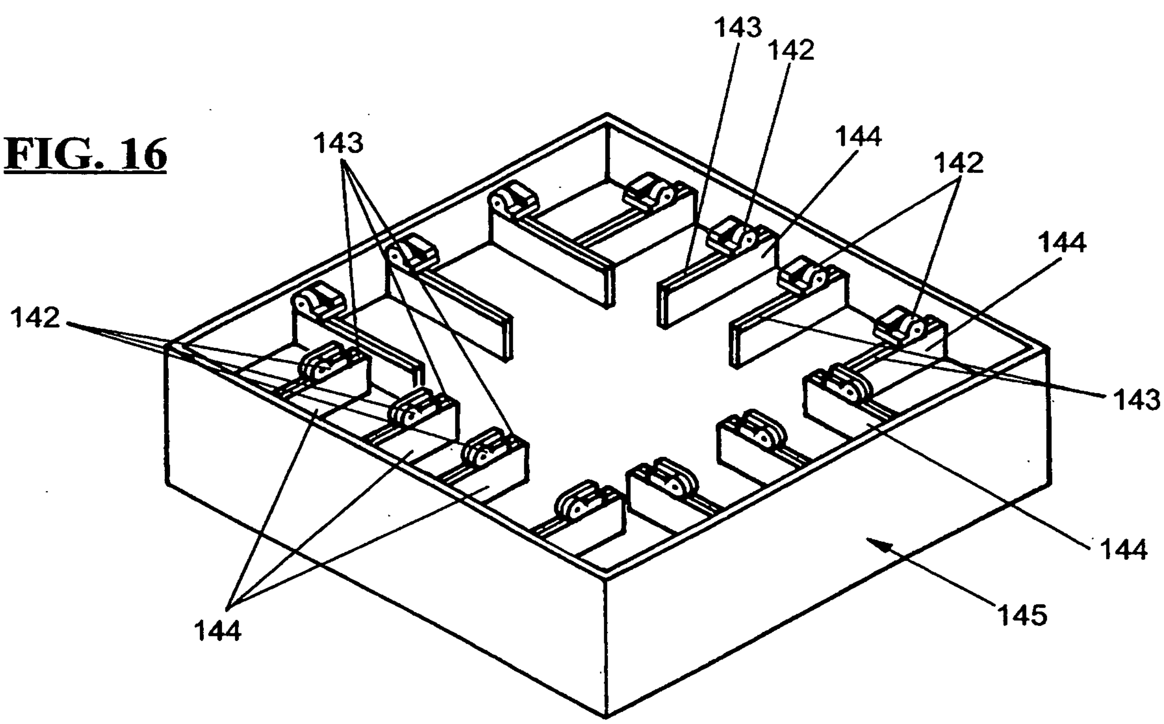


FIG. 16



INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ 99/00079

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^{6}: B29C 51/10, 51/14, 51/26, 51/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (6) : B29C 51/00, 51/10, 51/14, 51/26, 51/42,
IPC (3) : B29C 17/03

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 88625, A1 (E I DU PONT DE NEMOURS & Co.) 14 September 1983 (see figures 9-14 and their associated description)	1,14 23
X	EP 705679, A1 (ROEHM/Röhm GmbH) 10 April 1996	1,14
X,Y	US 4039643, A (Dean) 2 August 1977 (see figures 13-23)	23

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[X] See patent family annex

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20 August 1999	23 AUG 1999

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X	DE 4223785, C1 (MASCHINENFABRIK GEORG GEISS) 13 May 1993	1,14,23
X	JP 50-28979, A (NAGASE RUBBER Ind.) 19 September 1075	1,14,23
Y	DE 4311592, A1 (R & S STANZTECHNIK GmbH) 13 October 1994	1,14,23

INTERNATIONAL SEARCH REPORT
Information on patent family members

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Patent Document Cited in Search Report		Patent Family Member				
EP	88625	AU 12095/83	BR 8301059	CA 1204996	ES 520220	JP 58162312A2
		US 4457797	US 4526831			
EP	705679	DE 4435463				
US	4039643	-				
DE	4223785	AT 141856	EP 579937			
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						END OF ANNEX

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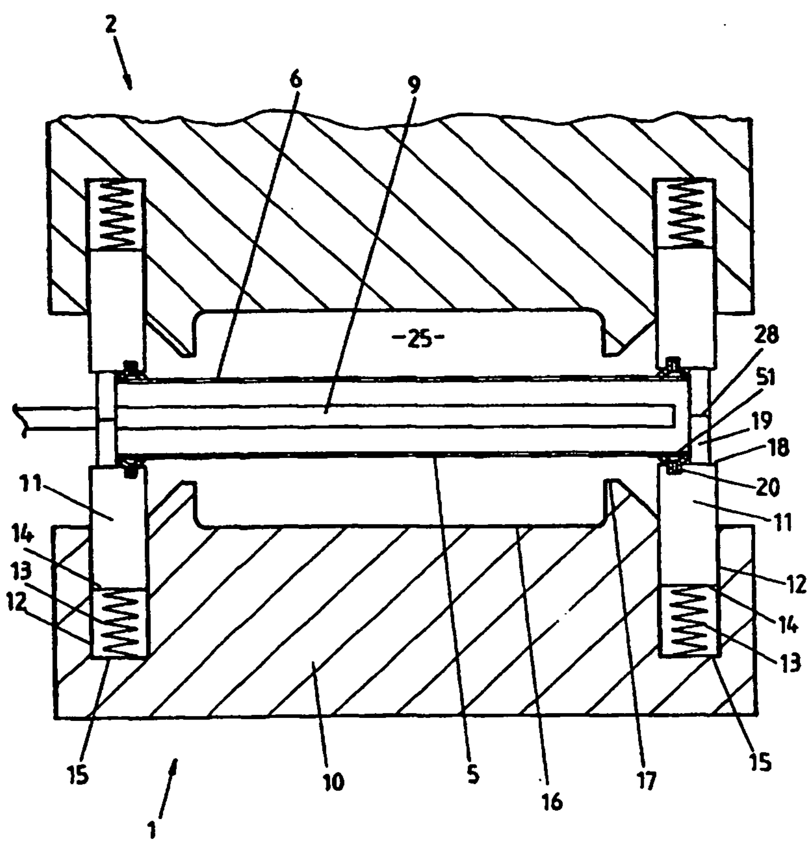
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: APPARATUS AND METHODS FOR TWIN SHEET THERMOFORMING

(57) Abstract

Apparatus for twin sheet thermoforming has each mould half incorporating a sheet support means which can hold a sheet by its edge and support the sheet during heating and wherein at least one of the sheet support means can retract during thermoforming. The sheets are supported clear of each mould half by the supports but are heated from between. A movable heater may carry sheets while simultaneously heating and transfer heated sheets to the mould halves of the thermoforming apparatus.



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